MEASURING POTENTIAL DERMAL TRANSFER OF SURFACE PESTICIDE RESIDUE GENERATED FROM INDOOR FOGGER USE: INTERIM REPORT

(Published in Chemosphere, Vol. 20, Nos. 3/4, pp. 349-360, 1990)

By

John Ross, Senior Toxicologist
Tian Thongsinthusak, Staff Toxicologist
Harvard R. Fong, Associate Environmental Hazards Scientist
Sheila Margetich, Agricultural Chemist II
Robert Krieger, Chief/Supervising Toxicologist

HS-1581 May 16, 1990

California Department of Food and Agriculture
Division of Pest Management, Environmental Protection, and Worker Safety
Worker Health and Safety Branch
1220 N Street, Sacramento, California 95814

Chemosphere, Vol.20, Nos.3/4, pp 349-360, 1990
Printed in Great Britain

0045-6535/90 $3.00 + .00
Pergamon Press plc

MEASURING POTENTIAL DERMAL TRANSFER OF SURFACE PESTICIDE RESIDUE GENERATED FROM INDOOR FOGGER USE: AN INTERIM REPORT

J. Ross*, T. Thongsinthusak, H.R. Fong, S. Margetich, R. Krieger: California Department of Food and Agriculture, Worker Health and Safety Branch, 1220 N Street, Sacramento, California 95814, (916) 445-8474

ABSTRACT

The transfer of pesticide residues from a carpeted floor to human subjects wearing dosimeter clothing was measured. Subject motions were standardized using aerobic dance routines (Jazzercise^{R}). This method allows reproducible exposure assessment and the derivation of transfer coefficients reflecting transfer of surface residues to exposed subjects.

Introduction

The use of home-foggers may result in detectable levels of pesticide on all exposed surfaces in the treated room. One of the largest deposition sites for these residues is the floor (Maddy et al., 1984). The potential interception area of carpeting increases with the addition of tight-weave carpeting and increases even greater with the use of high-low (sculpted) or shag (long-fibre) carpeting. Since this storage depot typically contains a majority of the non-volatile fogger contents (Maddy et al., 1987), there is also a considerable potential for dermal transference to an individual in contact with the carpet. This would be especially true in the case of individuals in close contact with the carpet, such as persons laying on the floor or crawling across the carpet. This study measured the amount of chlorpyrifos and d-trans allethrin residues from home foggers on carpets transferred to adults while performing a standardized set of movements on the floor.

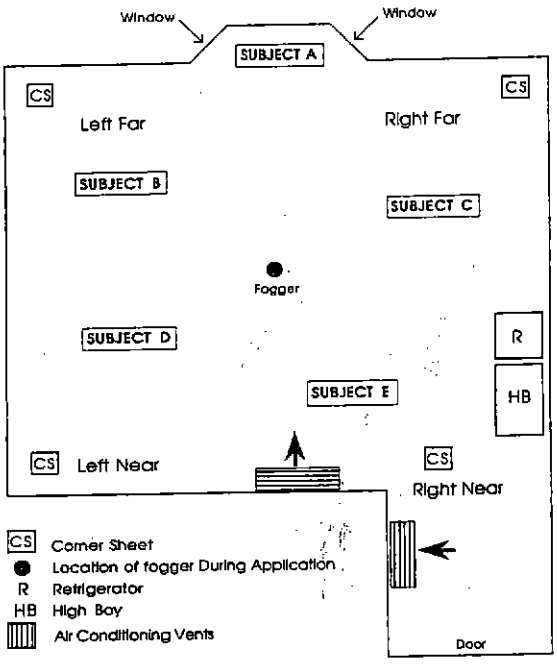
Materials and Methods

Eleven identical home-fogger devices, (K-RID Brand, K-Mart Stores distributors; EPA Reg. # 9688-63) which contain chlorpyrifos as the predominate active ingredient, were purchased in a local retail store. All chlorpyrifos-containing foggers are formulated and packaged by one company (Chemsico, St. Louis, MO). Foggers were weighed and the value marked on the body of the canisters to assist in later calculation of the amount of material ejected.

The study was conducted in a large, recently constructed hotel in Sacramento, California. Rooms on the second floor were isolated from each other with exit doors facing a common interior hallway. The rooms were cleared of as much furniture as possible, to optimize floor

surface area. The only furnishings not removed from the room were the highboy stand which housed the television and the small refrigerator next to the highboy. Both were covered with polyethylene film (0.004 inch). The polyethylene film was also used to seal the small entry vestibule that connected the room to the exit door and to seal off the small desk that was set into the wall. This sealing made the room walls a more uniformly flat surface (Figure One). Only the baywindow area was left unsealed. Available floor surface area and volume were 21.2 $\pm$ 0.1 m^2 and 51.8 $\pm$ 1.6 m^3, respectively. The rooms were photographed both before and after the rearrangement of the furnishings. All air conditioners were independent units with recirculating intake/exhaust as indicated in Figure One. Air conditioners were set to "OFF" during the application phase. However, both before and after the application phase, the air conditioners were set to "ON" (continuous fan operation) and "COOL" (intermittent compressor cycling). Smoke detectors were tightly sealed with plastic to prevent accidental triggering from the fogger. The rooms had uniform carpeting of 100% nylon which was periodically cleaned with commercial rug shampoo (RIGBEE™ brand, S.C. Johnson & Son, Inc.) and vacuumed after each occupancy. Temperature and relative humidity were recorded prior to activation of the fogger and upon label-allowed reentry and then hourly thereafter. Foggers were set-up according to label directions. A polyethylene-covered cinder block (40 cm) was used to elevate the fogger above the floor in the center of the room. Newspaper was placed between the cinder block and the fogger, as per label instructions.

FIGURE ONE - Room Configuration, Subject Layout



Five volunteers from State service participated in the study. Each had baseline cholinesterase levels established. All subjects were healthy. The subjects' descriptions are as follows:

TABLE ONE: Subject Physical Characteristics

Subject A: Male - 79 kg
Subject B: Female - 70 kg
Subject C: Male - 65 kg
Subject D: Male - 84 kg
Subject E: Female - 53 kg
Mean age of subjects: 36±4 years

In addition to underclothing, they wore the following dosimeter clothing which was pre-laundered once at a commercial cleaners.

A. One pair of 54% cotton, 36% polyester and 10% Spandex fabric tights (footless, white, #262 large, Gilda Marx Industries, Inc.).
B. One white HANES brand medium long-sleeved "T-shirt" of 100 % cotton.
C. Thin 100% cotton gloves.
D. White "athletic" socks of 100% cotton.

Four aluminum fallout sheets (400 cm^2, food-grade foil) were positioned near the corners of each room. The sheets were 1 meter from the corner on a vector transecting the room diagonally but not encroaching on the area of the carpet to be in contact with the test subjects. Adjacent to each sheet (within 10 cm) one gauze dosimeter was also placed. The dosimeter was constructed from a gauze pad (57.76 cm^2, 12 ply, Professional Medical Products Inc. Greenwood, SC) placed inside the dosimeter (Western Paperbox Company, Hayward, CA). The exposed surface of the gauze was 23.76cm^2.

The test rooms were identified as shown in Table Two. The study began at 2000 hours the night before subjects entered the rooms. The fogging set-up, as specified previously, was in place several hours earlier. The foggers were activated in the pattern shown in Table Two.

TABLE TWO: Schedule of Events for Dermal Contact Study

Room	Activate Time	Vent Time	Reentry Time
Room A12	2000 hours*	2200 hours	1030 hours
Room B13	2000 hours*	2200 hours	1130 hours
Room A6	0400 hours	0600 hours	1230 hours
Room B6	0500 hours	0700 hours	1330 hours
Room A0	1200 hours	1400 hours	1430 hours
Room B0	1300 hours	1500 hours	1530 hours
Room CX	CONTROL	0800 hours	0830 hours
Room CY	CONTROL	0900 hours	0930 hours

*previous night

Two hours after activation, the rooms were vented by opening the two bay-windows and activating the fan only of the air conditioner. The total open venting area was ~0.5 m^2. The exit doors were not opened since this would have caused contamination of the common hallway. Each room was vented for 30 minutes after which the windows were closed again. When support personnel entered treated rooms to open/close windows, take readings or samples, they wore disposable foot coverings (surgical shoe covers) to prevent cross contamination. During any reentry, the support personnel avoided disturbing the treated floor areas.

At the appropriate time intervals shown in Table Two, the test subjects entered the indicated room. They were wearing the required dosimeter clothing, along with foot coverings to prevent contamination from extraneous sources. These coverings were removed at the threshold of the exposure room and used to recover the feet during the exit. The coverings were discarded after each full use (entrance/exit) to prevent any cross-contamination. The subjects positioned themselves to allow maximum distance from each other. Layout of the room and the subjects is shown in Figure One.

The subjects had preassigned areas of the room in which they were to conduct their part of the study. This location did not vary from room to room. The area of the floor on which the fogger assembly sat was avoided, since it was covered by the application set-up during application and therefore not exposed to any potential fallout residue. This area was marked by adhesive tape. Prior to the start of the exposure experiment, the aluminum fallout sheets and the gauze dosimeters were collected, placed in 32 oz. wide mouth glass containers, sealed with food grade aluminum foil and capped with plastic caps. These containers were stored in insulated boxes on dry ice (~-70°C). The spent fogger canisters were collected and stored for later reweighing.

The subjects, having removed their footcovering and taken their assigned positions, were led through a series of Jazzercise^{R} routines by a certified instructor (Subject A). These routines are listed in Table Three. There were four separate routines, the first three of which were followed by a specific stretching exercise. These routines and stretches were timed and the times are listed in Table Three. The routines and stretches selected allowed for substantial contact of different body parts with the floor. The total time for the contact phase was 18.2 min. per room plus entry and exit time (total approximately 20 min.).

TABLE THREE: Jazzercise^{R} Routines and Stretches

Routine Name	Set Identification*	Time (min)
1. Get Out of My Dreams, Get Into My Car	**R3-88**	4:35
Stretch A - Extend legs, tilt torso	---	1:00
Stretch B - Pull feet to diamond	---	0:30
2. Rock Steady	**R4-87**	3:56
Stretch C - Roll to abdomen, elbow support	---	1:00
3. Family Man	**R3-88**	3:47
Stretch D - High knee sit, glut. tilt each side	---	0:30
4. I Need You Tonight	**R1-88**	2:56

*JAZZERCISE^{R} Set Identification Number

At the end of the Jazzercise^{R} "class", the subjects removed their cotton gloves, placed them in plastic bags (ZIP-LOC brand) and covered their hands with PVC gloves. They then removed their socks, recovering their feet with the foot coverings, placed the socks in plastic bags, then exited the room. The subjects returned to an untreated room where they removed the remaining dosimeter clothing. They then discarded their PVC gloves and dressed in the dosimeter clothing required for the next exposure period. The exposed clothing articles (gloves, socks, tights, and shirt), after being placed in their individually marked plastic

bags, were stored on dry ice. The subjects wore fresh dosimeter clothing for each room.

The spent fogger containers were reweighed and the amount of released active ingredient calculated. All the exposed sampling media (clothing, foil, gauze) were sent to CDFA Chemistry Laboratory Services for extraction and analysis. The samples were analyzed for chlorpyrifos, its oxon analog, and d-trans allethrin. Chlorpyrifos, oxon and d-tran allethrin were extracted from aluminum foil and cotton matrices using ethyl acetate. The samples were placed in jars large enough to allow a sufficient amount of ethyl acetate (1000 ml for aluminum, 750 ml for small cotton items, 2500 ml for large cotton items) to extract the residues. Samples were rotated on mechanical rollers for 30 minutes. The extract was analyzed by gas chromatography equipped with electron capture detector under the following conditions: HEWLETT-PACKARD 5880A gas chromatograph; Oven temp., 180°C; Injector temp., 225°C; Detector temp., 350°C; Capillary configuration: Col. pressure, 20 psi; Split vent, 50 ml/min; Split purge, 2 ml/min; Argon/methane makeup gas, 60 ml/min. Retention times were, for chlorpyrifos: 5.99 minutes, for the oxon: 5.78 minutes and for d-trans allethrin: 8.29 minutes.

Results

Spiking of clothing and floor dosimetry media during the actual fogger study (Table Four) demonstrated the excellent recoveries under the conditions of collection, storage and analysis. There was both allethrin and chlorpyrifos in all exposure samples exceeding the minimum detection limits (MDL). With the exception of socks, the control typically contained no chlorpyrifos or allethrin. Chlorpyrifos oxon was not detected at any time in any of the samples.

TABLE FOUR: Recoveries and Detection Limits During Fogger Study (n = 3 per item type)

ITEM	SPIKE (mg)	MEAN PERCENT RECOVERY CHLORPYRIFOS	OXON	d-trans ALLETHRIN
Shirt	0	(5)[a]	(10)	(25)
"	5	100	105	104
Tights	0	(5)	(10)	(25)
"	5	95	98	100
Socks	0	(5)	(2)	(5)
"	1	102	104	104
Gloves	0	(1)	(2)	(5)
"	1	100	97	101
Gauze	0	(1)	(2)	(5)
"	0.1	102	105	105
Foil	0	(0.2)	(0.4)	(1)
"	0.4	102	105	102
XAD-2	0	(0.1)	(0.2)	(1)
"	0.5	103	95	101

[a]For 0 mg spikes, minimum detectable level reported in ug/sample in parentheses.

Ambient outdoor temperatures during the study ranged from a low of 70°F (21°C) to a high of 108°F (42°C). This necessitated the use of air conditioners during the course of the study except during the 2 hour fogging and the half-hour venting. Mean indoor temperature was 74°F and mean relative humidity was 63 percent.

Videotape and on-site observation of foggers being started showed the tendency of the aerosol plume to angle (5-10° right of vertical) in the direction that the initiating tab was depressed. Because the same right-handed individual started all foggers, the tab was always on the right side of the room when facing the windows. The preferential distribution of fogger contents can be seen in the results of dosimeter pad deposition in Tables Five and Six.

TABLE FIVE: Corner Located Fallout Dosimeter Results for Chlorpyrifos Residue on Aluminum Foil and Gauze (ug/cm^2)

	PAD LOCATIONS							
ROOM	RIGHT NEAR		RIGHT-FAR		LEFT-NEAR		LEFT-FAR	
ID #	ALUM	GAUZ	ALUM	GAUZ	ALUM	GAUZ	ALUM	GAUZ
A0	1.35	1.51	2.66	2.77	1.30	1.68	2.38	2.90
B0	2.16	2.36	3.27	3.75	2.06	1.57	1.69	2.34
A6*	1.59	2.65	1.34	2.23	1.62	2.70	0.78	1.30
B6*	2.85	4.75	0.28	0.47	1.75	2.92	0.88	1.47
A12	1.18	2.34	0.81	2.08	0.93	2.20	0.20	1.75
B13	0.53	1.83	0.52	1.99	0.60	1.94	0.31	2.02

*gauze values from interpolation.

TABLE SIX: Corner Located Fallout Doismeter Results for d-trans Allethrin Residue on Aluminum Foil and Gauze (ug/cm^2)

	PAD LOCATIONS							
ROOM	RIGHT NEAR		RIGHT-FAR		LEFT-NEAR		LEFT-FAR	
ID #	ALUM	GAUZ	ALUM	GAUZ	ALUM	GAUZ	ALUM	GAUZ
A0	0.15	0.16	0.31	0.28	0.15	0.17	0.28	0.28
B0	0.20	0.20	0.32	0.31	0.21	0.14	0.16	0.20
A6	0.25	NS	0.23	NS	0.25	NS	0.14	NS
B6	0.40	NS	0.11	NS	0.28	NS	0.18	NS
A12	0.24	0.28	0.20	0.24	0.20	0.25	0.10	0.19
B13	0.17	0.23	0.19	0.26	0.19	0.26	0.16	0.25

NS - no sample

Tables Seven and Eight summarize the results of analysis of dosimeter clothing for chlorpyrifos and allethrin, respectively, worn by five individuals exercising in six rooms which had been fogged then vented at various times prior to entry. Results of control rooms are not shown because only the socks contained any pesticide above the MDL. The control sock exposure is thought to have occurred as a result of contamination which was tracked from treated rooms into the control rooms on the feet of support personnel. It is apparent from the tables that potential dermal exposure as measured by pesticides on the dosimeter clothing was quite reproducible and that for both pesticides the potential dermal exposure declines with time.

TABLE SEVEN: Mean Accumulated Chlorpyrifos Residue on Dosimeter Clothing (ug/article, n = 5)

Time Post-Venting and Room ID	Tights	Shirt	Socks	Gloves
0 Hr / Rm A	1229 ± 514	1043 ± 651	754 ± 253	459 ± 253
0 Hr / Rm B	1192 ± 647	946 ± 617	1025 ± 479	570 ± 352
6 Hr / Rm A	857 ± 559	664 ± 453	563 ± 289	320 ± 188
6 Hr / Rm B	853 ± 648	557 ± 287	706 ± 541	372 ± 308
12 Hr / Rm A	497 ± 146	319 ± 84	381 ± 77	163 ± 53
13 Hr / Rm B	298 ± 97	274 ± 59	268 ± 96	117 ± 46

TABLE EIGHT: Mean Accumulated d-trans Allethrin Residue on Dosimeter Clothing (ug/article, n = 5)

Time Post-Venting and Room ID	Tights	Shirt	Socks	Gloves
0 Hr / Rm A	108 ± 36	97 ± 49	76 ± 24	60 ± 28
0 Hr / Rm B	102 ± 59	86 ± 61	106 ± 62	68 ± 43
6 Hr / Rm A	85 ± 55	73 ± 42	67 ± 33	48 ± 29
6 Hr / Rm B	91 ± 55	72 ± 28	86 ± 69	60 ± 47
12 Hr / Rm A	55 ± 12	45 ± 10	40 ± 17	23 ± 11
13 Hr / Rm B	40 ± 12	39 ± 6	30 ± 14	23 ± 9

If the data in Tables Seven and Eight is presented graphically (Figures Two and Three) with each point representing the mean of total potential dermal exposure of ten replicates from each time point, the rate of decline in accumulation of pesticide residue from carpeting is clearly rapid. These graphs may have been more appropriately drawn as bar graphs since the pesticides were transferred to clothing over approximately 20 minute periods. However, as curvilinear graphs it is possible to take the area under the curve to approximate the potential dermal exposure as though the exposure were continual. These approximations of continual exposure will be used subsequently to calculate "extreme case" dosages of chlorpyrifos following fogger use. Because the same five individuals took part in all six Jazzercise^{R} periods in rooms treated at various times prior to entry, it is possible to calculate the total potential dermal dose by summing the column values in Tables Seven. Assuming a clothing penetration factor of 10% and dermal penetration of 3% for chlorpyrifos, (Nolan et al., 1984) the subjects studied potentially received a mean absorbed dosage of 43 ug of chlorpyrifos over the 2 hours of actual exposure time. By dividing the amount of pesticide on each piece of dosimeter clothing by the mean total accumulated on all of the clothing for each person, it was possible to determine the relative contribution of each exposed area to the total exposure. Because the distribution of total transferred pesticide is so uniform with respect to both time and between compounds (Table Nine), it is another indication of the high degree of reproducibility that exposure choreographed to music allows.

FIGURE TWO - Chlorpyrifos on Clothing Dosimeters

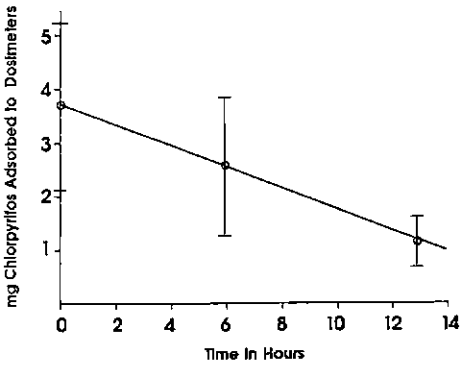


FIGURE THREE - Allethrin on Clothing Dosimeters

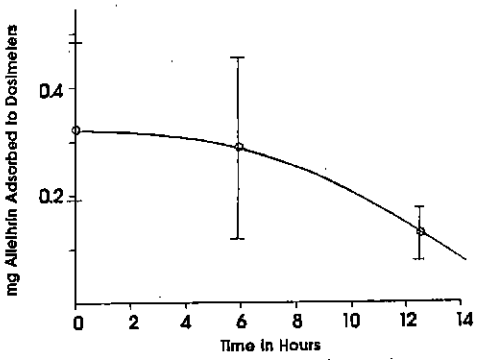


TABLE NINE: Mean Percent Total Chlorpyrifos and d-trans Allethrin Residue Accumulated on Dosimeter Clothing[a] (Chlorpyrifos in **Bold Type**)

Time Post-Venting	Tights	Shirt	Socks	Gloves
0 Hours	**33.6 ± 16.1**	**27.6 ± 17.6**	**24.5 ± 10.1**	**14.3 ± 8.4**
0 Hours	30.0 ± 13.1	26.0 ± 15.7	25.9 ± 12.1	18.2 ± 10.2
6 Hours	**35.0 ± 24.7**	**25.0 ± 15.2**	**25.9 ± 16.9**	**14.2 ± 10.1**
6 Hours	30.4 ± 19.0	25.1 ± 12.4	26.2 ± 17.2	18.5 ± 13.2
12.5 Hours	**33.9 ± 10.5**	**26.0 ± 6.2**	**28.0 ± 7.9**	**12.2 ± 4.4**
12.5 Hours	31.9 ± 8.3	28.6 ± 5.5	23.7 ± 10.6	15.9 ± 6.9
Grand Mean	**34.2 ± 17.1**	**26.2 ± 13.0**	**26.1 ± 11.6**	**13.6 ± 7.6**
Grand Mean	30.8 ± 13.5	26.6 ± 11.2	25.3 ± 13.3	17.5 ± 0.1

a-Calculated by dividing mean residue accumulated on each clothing article by the mean total residue accumulated on each subject's clothing at that interval.

The amount of each pesticide on dosimeter clothing was divided by the body surface area that piece of clothing represented; i.e., shirt's values were divided by 7440 cm^2, pants by 7220 cm^2, gloves by 1310 cm^2 and socks by 1220 cm^2 (EPA, Subdivision U, 1987) to arrive at a residue level of ug/cm^2 in each body part. One method of calculating a transfer coefficient (i.e., the percentage of pesticide on the floor that is physically transfered to the dosimeter clothing) is to divide the pesticide concentration (in ug/cm^2) on clothing by the pesticide concentration on the floor with which the person was in contact. In order to reduce variability from contribution of any one value for floor residue and to arrive at the best approximation of floor residue in the area that each test subject exercised, the floor residues were treated in the following manner:

Subject	Associated Gauze Corner Pad Residue Value
A	(Left Far + Right Far)/2
B	(Left Near + Left Far)/2
C	(Right Near + Right Far)/2
D	(Left Near + Left Far)/2
E	(Right Near + Right Far)/2

Transfer coefficients can be used to calculate potential dermal dose to a human when the only information available is surface residue. This study presents the opportunity to compare various methods of calculating potential dermal dose to actual measures of dose (i.e., whole body dosimetry). One motivation for performing this exposure study was to compare actual exposures following fogger usage to the hypothetical calculations of chlorpyrifos dosage to an infant (Berteau et al., 1989). There are numerous ways the data from the current study could be used to calculate dosage to an infant. One possibility is to adjust for dermal exposure by taking the ratio of the body surface areas for an infant (3,925 cm^2; Snyder et al., 1974) divided by an adult (21,000 cm^2; EPA, 1987) and multiplying by the appropriate area under the curve shown in Figures Two and Three. When this is done from the label-allowed child reentry (6 hours) to 12 hours for chlorpyrifos, a total potential dermal exposure of 2.4 mg results, compared to the Berteau (op.cit.) value of 19.9 mg. The present dermal exposure estimate necessarily overestimates exposure. Overestimation of exposure primarily comes from exposure being estimated as though the child were continually in contact with the treated surface and in continuous motion. Secondly, the estimate contains no mitigation for any clothing, including diapers.

Transfer declines precipitously between six and tweleve hours for both chlorpyrifos and d-trans allethrin. This may reflect several possible factors:

1. Loss of formulation inerts (existence of pesticides in thin films of "inert" solvents/emulsifiers could make them more available for transfer until inerts are lost via evaporation/absorption/adsorption, etc.).
2. Permeation of carpet fibres by the pesticide (absorption).
3. Breakdown to non-detected materials (chemical degradation, e.g., hydrolysis, oxidation).
4. Binding to carpet fibres by the pesticide (adsorption).
5. Migration downward into non-contact area (e.g. carpet backing or foam pad), either alone or adsorbed to dust particle.
6. Volatilization.

The decrease in transferability with time from a previously untouched surface tends to produce overestimates of exposure generated solely from deposition data. As indicated by the large drop in transfer coefficient between 6 hours and 12 hours (Table Ten), it is apparent that transfer decreases up to 50 percent faster than decay of residues. Another key factor is that each succeeding contact with a particular carpeted area produces a diminishing return of transfer.

The use of both gauze and foil pads provided an interesting insight into the difference in dissipation of chlorpyrifos on adsorbing vs. non-adsorbing surfaces. It is reasonable to assume that volatilization from a smooth metallic surface would be more rapid than from fiber to which a compound was adsorbed (Cohen and Popendorf, 1989), since the process of adsorption involves physical bonding forces (e.g., Van der Waal's) which must be overcome in addition to the energy required for volatilization. Nylon carpeting is undoubtedly more adsorbent than aluminum foil but probably less adsorbent than cotton.

The locations of the corner pad as related to the subjects is shown in Figure One. If the clothing residue values are divided by the appropriate floor residues calculated from Tables Five and Six and the results multiplied by 100, a transfer coefficient is derived. These transfer coefficients decline with time for both pesticides as shown in Table Ten.

TABLE TEN: Mean Percent Total Chlorpyrifos and d-trans Allethrin Transfer Coefficients (ug/cm^2 clothing: ug/cm^2 corner fallout gauze) (Chlorpyrifos in **Bold Type**)

Time Post-Venting	Tights	Shirt	Socks	Gloves
0 Hours	**6.6 ± 1.6**	**5.6 ± 2.6**	**32.1 ± 13.4**	**17.4 ± 8.6**
0 Hours	5.9 ± 1.5	5.4 ± 2.4	34.3 ± 18.3	22.4 ± 12.6
6 Hours	**7.5 ± 4.6**	**6.3 ± 5.8**	**33.3 ± 12.9**	**16.9 ± 11.0**
6 Hours	5.3 ± 2.0	4.8 ± 2.5	27.1 ± 8.8	17.9 ± 9.1
12.5 Hours	**4.0 ± 1.3**	**3.1 ± 0.5**	**20.3 ± 3.5**	**8.1 ± 1.9**
12.5 Hours	3.0 ± 0.8	2.8 ± 0.5	13.7 ± 4.7	8.3 ± 2.7

DISCUSSION AND CONCLUSIONS

Concern over the exposure of individuals at increased risk following exposure to insecticides (e.g., infants, chronically ill, very old) will continue in the absence of solid data (Berteau et al., 1989). While the type of study reported can provide valuable exposure data under controlled conditions and provides some assurance that actual exposures are probably not as great as may have been earlier hypothesized, exposure measurements under actual use conditions continue to be indirect (Immerman, et al., 1988). Collecting exposure data indirectly by measuring surface and air concentrations requires numerous assumptions in extrapolating these data to actual delivered dosage. It is ironic that knowledge of exposure under actual use conditions is so limited considering the widespread usage of these chemicals and the length of time many of these pesticides have been employed in the home.

Human exposure data for pesticides applied indoors is very minimal. Part of the difficulty arises from not having standardized exposure assessment methodology. This study addressed that problem by using a standardized aerobic dance program (Jazzercise^R) and human volunteers dressed in dosimeter clothing. The amount of material detected on the dosimeter clothing, compared to the residue levels estimated on the floor (from fallout sheets) allows for the development of an empirical transfer coefficient for human exposure. This transfer coefficient can be compared to availability of residues assessed by wiping the treated carpet with cloth. The data generated from this study provides an indication of transferability of pesticides under indoor exposure conditions, which is currently a largely unknown factor in dermal exposure. These data seem of fundamental importance for human exposure assessments in both indoor and outdoor settings. The relative distribution of the total dose on the body surface (see Table Nine) can be used to suggest mitigation measures (i.e., wearing a shirt, pants and socks would reduce potential exposure by >70%) and also to establish a quantitative estimate of alternative exposure e.g., the hands' contribution to an oral component of exposure if placed in the mouth or on food.

Calculation of percentage of fogger contents landing on the floor can be estimated for both chlorpyrifos and allethrin (69% and 55%, respectively for all available test rooms). These figures are substantially lower than some hypothetical estimates derived from Maddy et al. (1987) for propoxur-containing foggers (100% floor deposition). Because both environmental levels and body dosimeter levels were taken, this study provides a link between environmental levels and human exposure allowing better extrapolation of exposure from indirect measurements.

Estimating exposure to pesticides from measurements in the indoor environment necessitates going beyond measuring ambient air levels or surface levels of these chemicals. Modeling exposure requires knowledge of a number of factors including the water solubility, reactivity, volatility, and the relative partioning preference between surfaces (such as foam pads) and the air, which are imparted by the physicochemical properties of the particular pesticide. Modeling exposure also requires knowledge of the relative amount of time spent indoors and the activity levels, extent of respiratory uptake, dermal transfer rate (including protection offered by normal clothing), types of heating/cooling systems used, amount of house dust and the type of floor covering. By experimentally determining some of the assumed values, more realistic estimates may indicate orders of magnitude lower exposure, though these may still be biologically significant.

The reproducibility of this method is a great advantage. It is timed to music (choreographed) and can be understood by anyone familiar with Jazzercise^{R}. With a larger data base including more chemicals, it should be possible to develop generic transfer coefficients similar to ones developed for transfer of dislodgeable foliar residues to agricultural workers (Zweig et al., 1985).

In making the assumption that dosimeter clothing can be used to estimate dermal exposure many factors are involved. Some have argued that clothing will bind pesticides more efficiently and is a larger reservoir for binding than skin. However, skin, depending on its degree of hydration, surface oils, area of absorption and temperature, has the potential for being just as good or better than cloth in adsorbing and absorbing pesticides at low concentrations. This question of the utility of cotton patches or dosimeter clothing appropriateness in estimating dermal exposure is one which begs an answer. Subsequent experimentation to answer this question and to determine the biovailability of the pesticides studied in this report is planned.

Bibliography

Berteau, P.E., J.B. Knaak, D.C. Mengle, and J.B. Schreider: Insecticide Absorption from Indoor Surfaces. American Chemical Society Symposium Series 382, pp. 315-326. (1989).

Cohen, B. and W. Poppendorf: A Method for Monitoring Dermal Exposure to Volatile Chemicals. Am. Ind. Hyg. Assoc. J., 50, 216-223 (1989).

Immerman, F.W., G.A. Rush, S.M. Jones, D.E. Camann, H.J. Harding, H.J. Schattenberg, and J.P. Hsu: Nonoccupational Pesticide Exposure Study (NOPES), Phase III Interim Report, Vols. 1 and 2. RTI/122/01-02F, Research Triangle Institute, Research Triangle Park, North Carolina (1988).

Maddy, K.T., S. Edmiston, and E. Ochi: Dissipation of DDVP and Propoxur Following the Release of an Indoor Fogger - A Preliminary Study. Calif. Dept. Food & Agric., Health and Safety Report #1259 (unpublished data) (1984).

Maddy, K.T., K.S. Goh, S. Edmiston, and S. Margetich: Dissipation and Consequent Possible Dermal Exposure Hazards of DDVP and Propoxur on Horizontal Surfaces Following the Release of Insecticide with an Indoor Fogger. Calif. Dept. Food & Agric., Health and Safety Report #1334 (unpublished data) (1987).

Nolan, R.J., D.L. Rick, N.L. Freshour and J.H. Saunders: Chlorpyrifos: Pharmacokinetics in Human Volunteers. Toxicol. Appl. Pharmacol. 73, 8-15, (1984).

Snyder, W.S., M.J. Cook, E.S. Nasset, L.R. Karhausen, G.P., Howells, and I.H. Tipton: Report of the Task Group on Reference Man. International Commission on Radiological Protection No. 23. Pergamon Press, Oxford, England (1974).

United States Environmental Protection Agency (EPA): Pesticide Assessment Guidelines, Subdivision U. (1987).

Zweig, G., J.T. Leffingwell, and W. Popendorf: The Relationship between Dermal Pesticide Exposure by Fruit Harvesters and Dislodgeable Foliar Residues. J. Environ. Sci. Health, 20 (B), 27-59 (1985).

Acknowledgements

The authors wish to thank the following individuals for their assistance in the execution of this study: Stan Bissell, Jesus Leyva, Linda O'Connell, David Haskell, Janet Spencer, Frank Schneider, Dana Meinders, Cathy Morman, Charlene Evans, and Smitty de Dogg. Also, the authors wish to thank Jazzercise, Inc. for their gracious cooperation. Use or mention of specific products in this report is in no way an endorsement of such products by the California Department of Food and Agriculture or the State of California nor is criticism implied of similar products not mentioned.

(Received in USA 5 November 1989; accepted 3 January 1990)